KIODO 2009: Trials and Analysis

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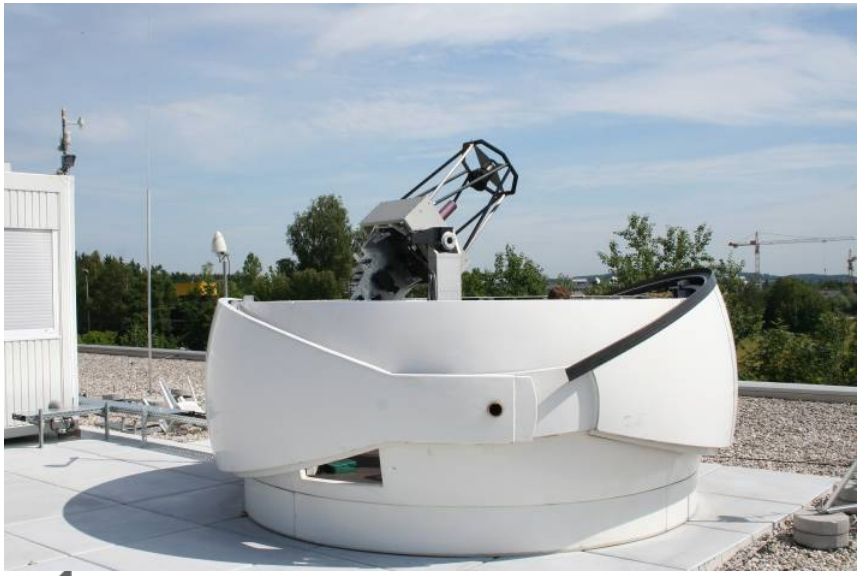
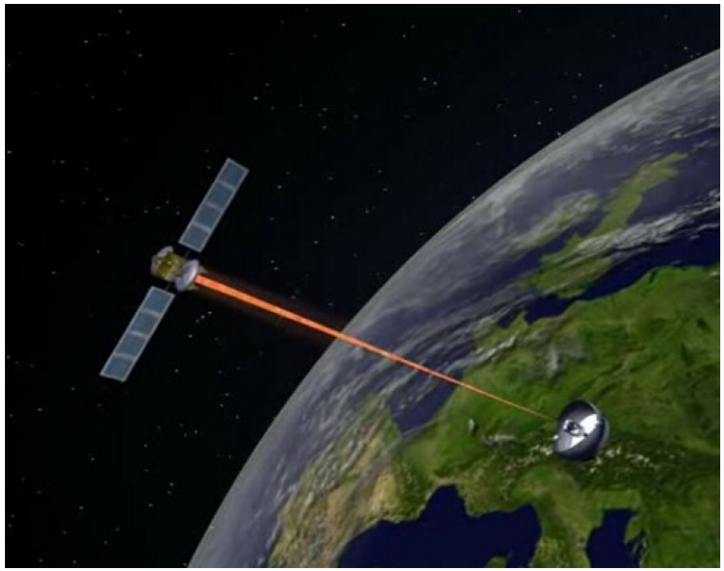
Scenario description: Optical ground station

- KIODO = KIrari's Optical Downlink to Oberpfaffenhofen
- Downlink from Kirari to ground station in Oberpfaffenhofen, Southern Germany
- Ground station on roof top of institute building, 583m above sea level
- Performed in June-September 2009

Optical Ground Station Oberpfaffenhofen (OGS-OP)



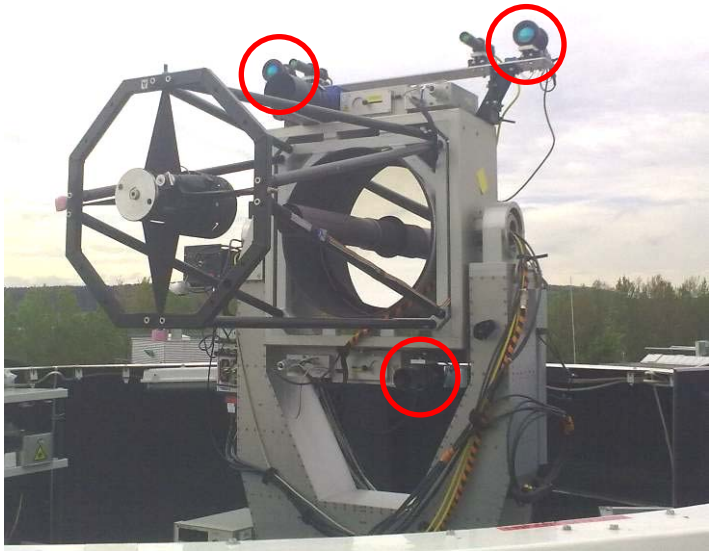
Scenario Illustration



Scenario description: Optical ground station

- 40cm Cassegrain telescope and 5cm refractor
- Fork mount with azimuth and elevation axes

40cm telescope, 5cm telescope, beacons



Backside

Scenario description: Overview satellite downlinks

- Overview of performed trials with minimum and maximum elevation of successful power reception
- Five trials successful, five other not due to weather conditions

Trial No	Date	Weather conditions	Link established	Min. el.	Max. el.
01	24/ Jun/ 09	Rain	No	-	-
02	26/ Jun/ 09	Rain	No	-	-
03	1/ Jul/ 09	Almost clear sky	Yes	11°	57°
04	3/ Jul/ 09	Overcast	No	-	-
05	19/ Aug/ 09	Almost clear sky	Yes	3°	35°
06	21/ Aug/ 09	Clear sky	Yes	10°	27°
07	26/ Aug/ 09	Cloudy, drizzle	Yes	6°	7°
08	28/ Aug/ 09	Clear sky	Yes	4°	49°
09	2/ Sep/ 09	Overcast	No	-	-
10	4/ Sep/ 09	Overcast, rain	No	-	-

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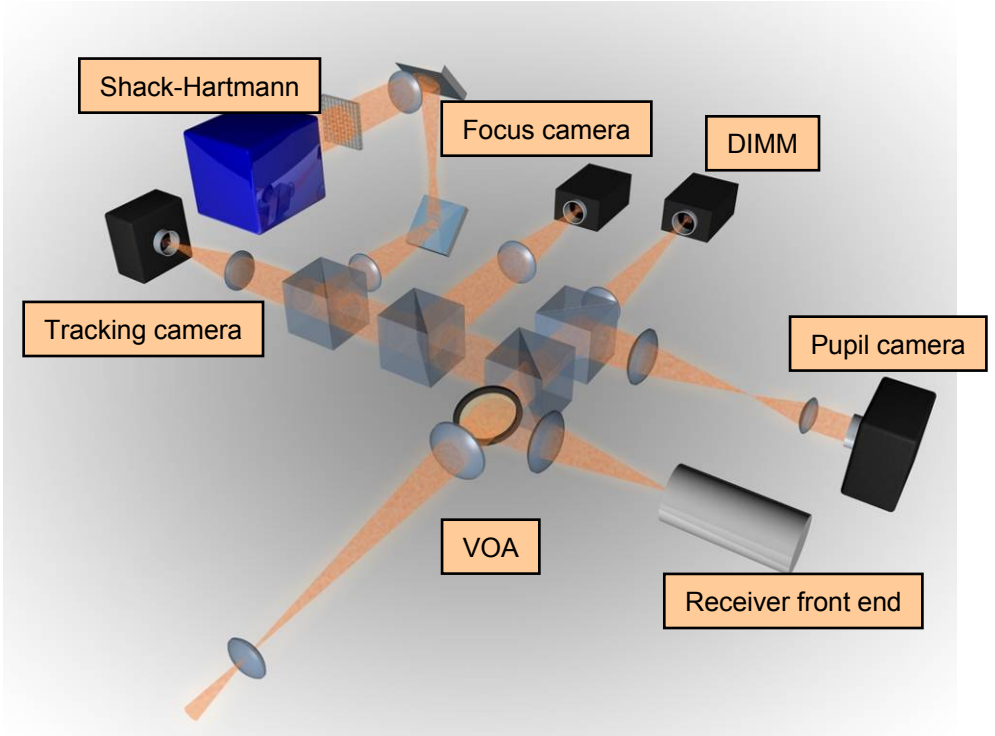
Measurement instruments

- Measurements performed with two telescopes → 40cm and 5cm apertures
- Behind 40cm telescope, the beam is split several times and guided to the respective sensors

Measurement instruments

- 40cm aperture
  - Receiver front-end (power meter)
  - Pupil camera
  - Focus camera
  - Differential image motion monitor
  - Shack-Hartmann wavefront sensor
- 5cm aperture
  - Power meter

Optical system behind 40cm aperture



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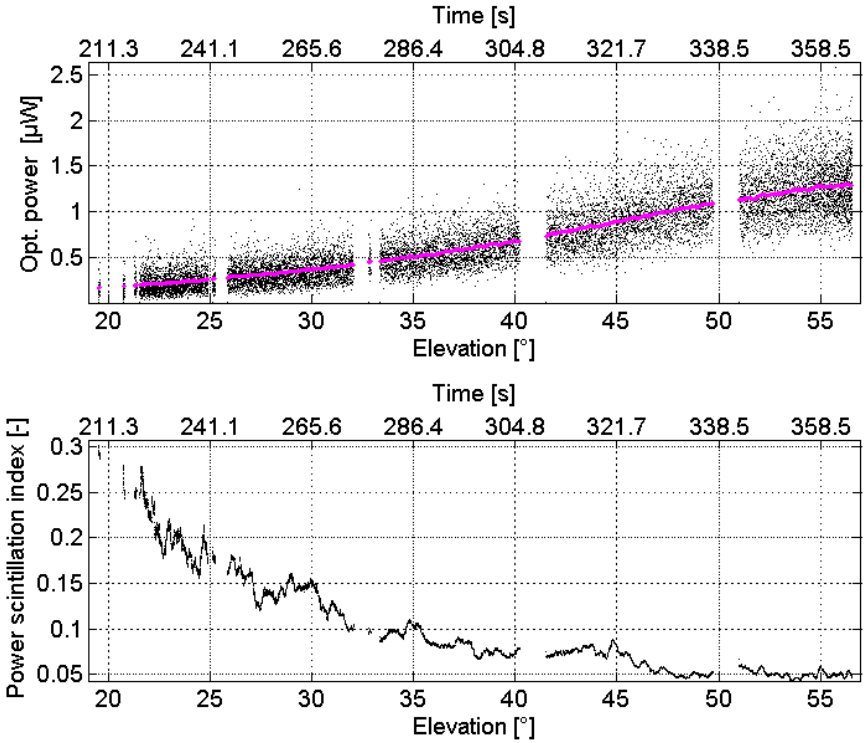
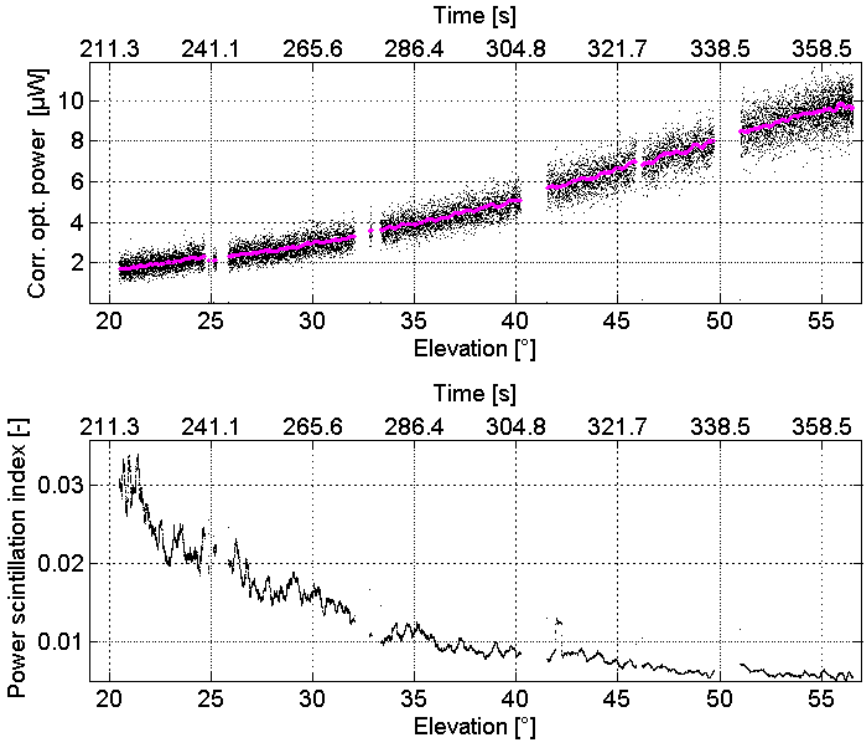
Analysis: Power measurements

- Power sampled at 20kHz
- Received power and scintillation index over elevation in Trial #03

5cm aperture



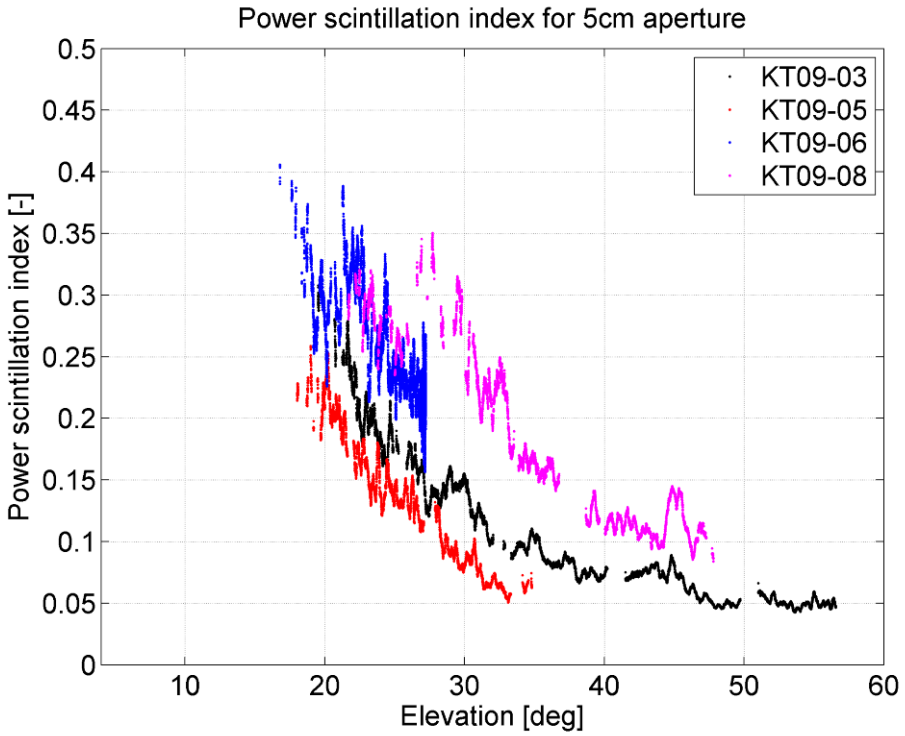
40cm aperture



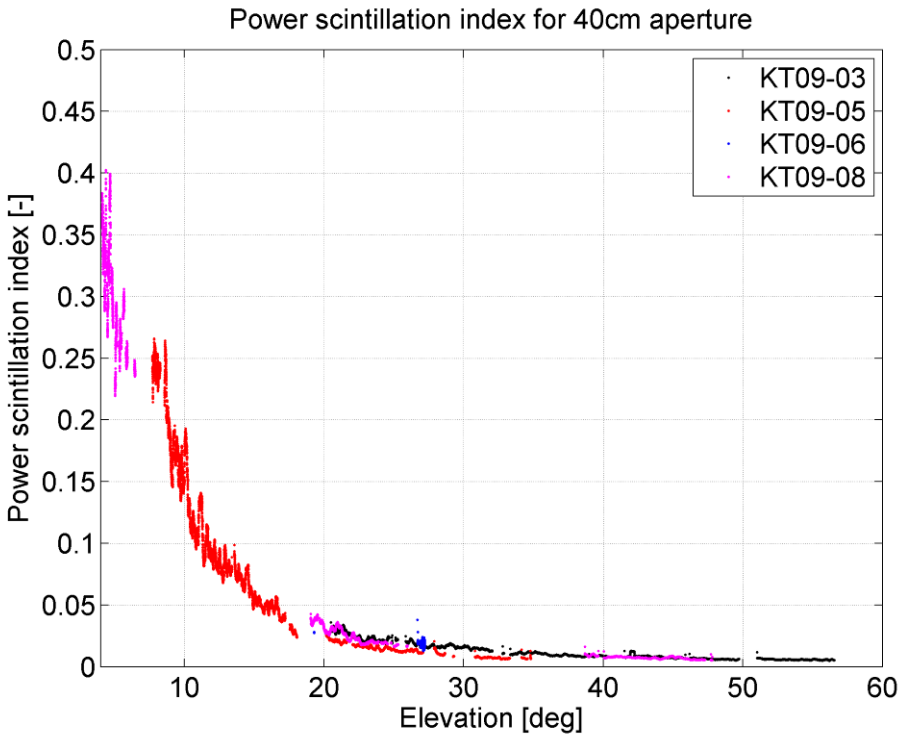
Analysis: Power measurements

- Power scintillation index over elevation for Trials #03, 05, 06, 08

5cm aperture



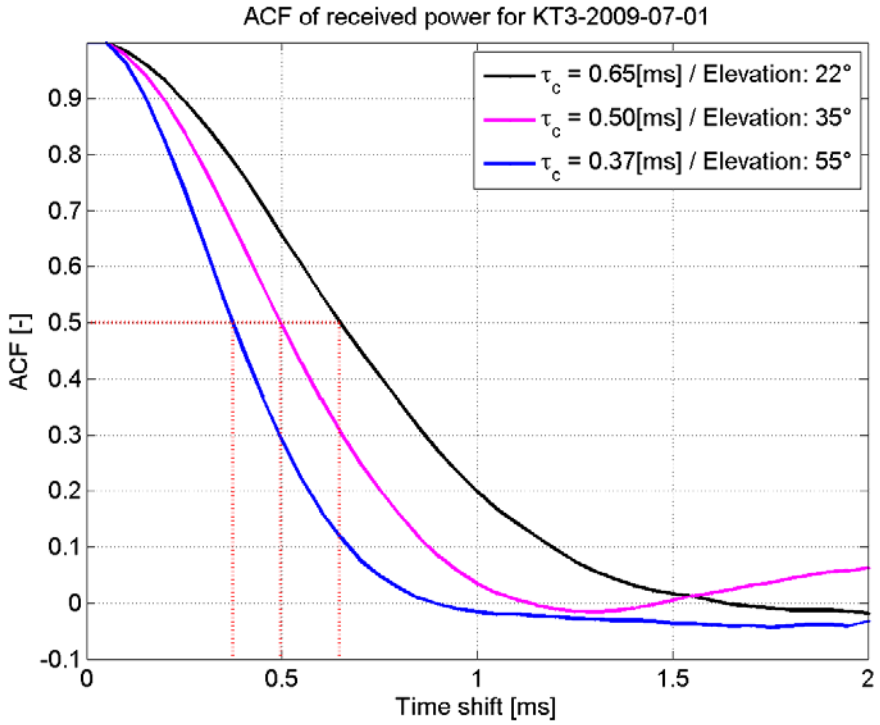
40cm aperture



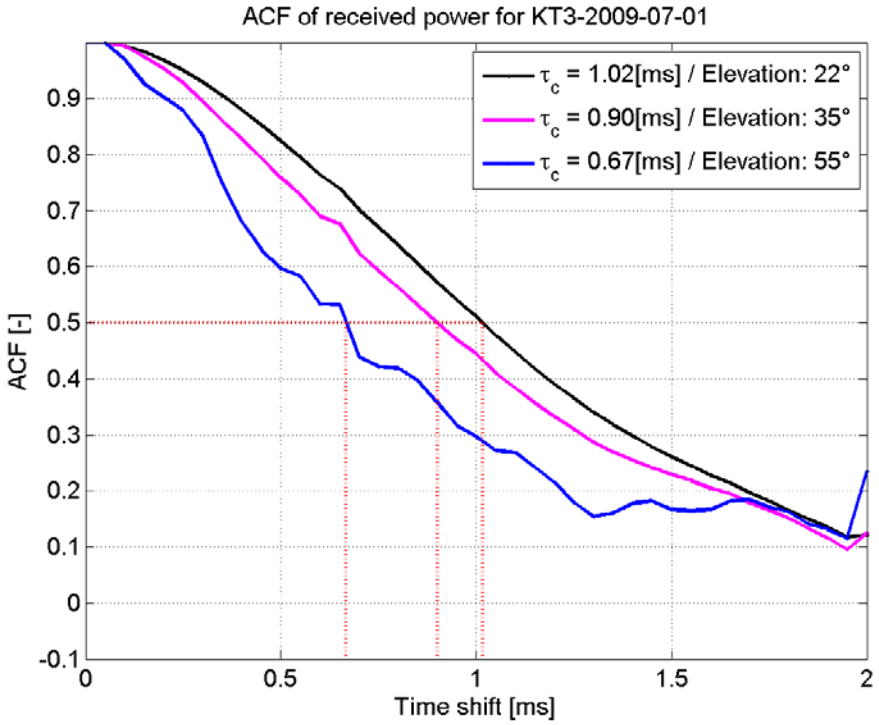
Analysis: Power measurements

- Normalized auto covariance function of power vector in Trial #03
- 50% correlation time of power vector → Half width at half maximum

5cm aperture



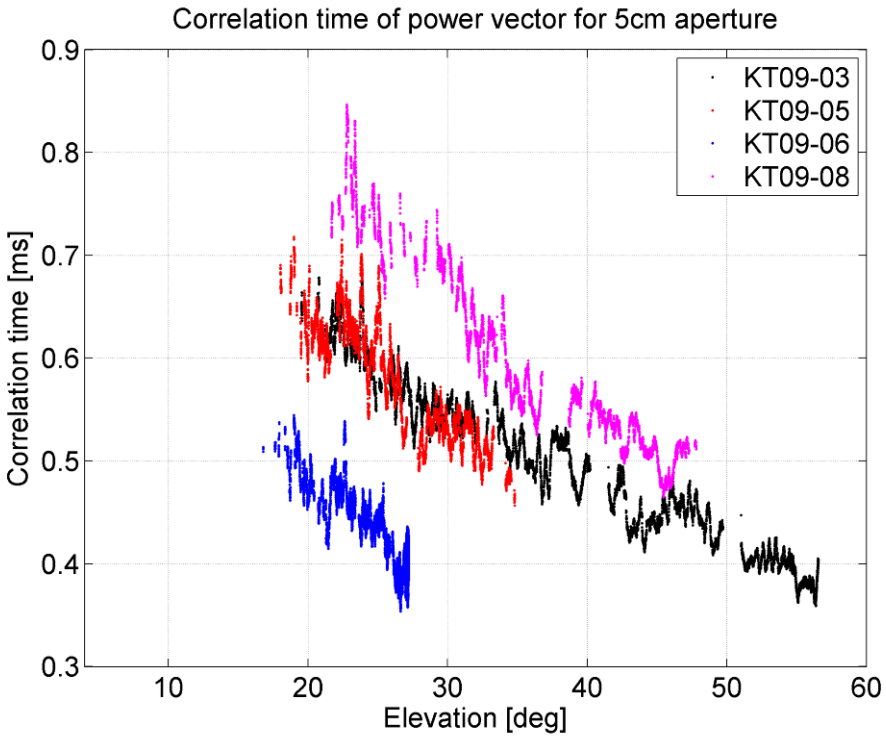
40cm aperture



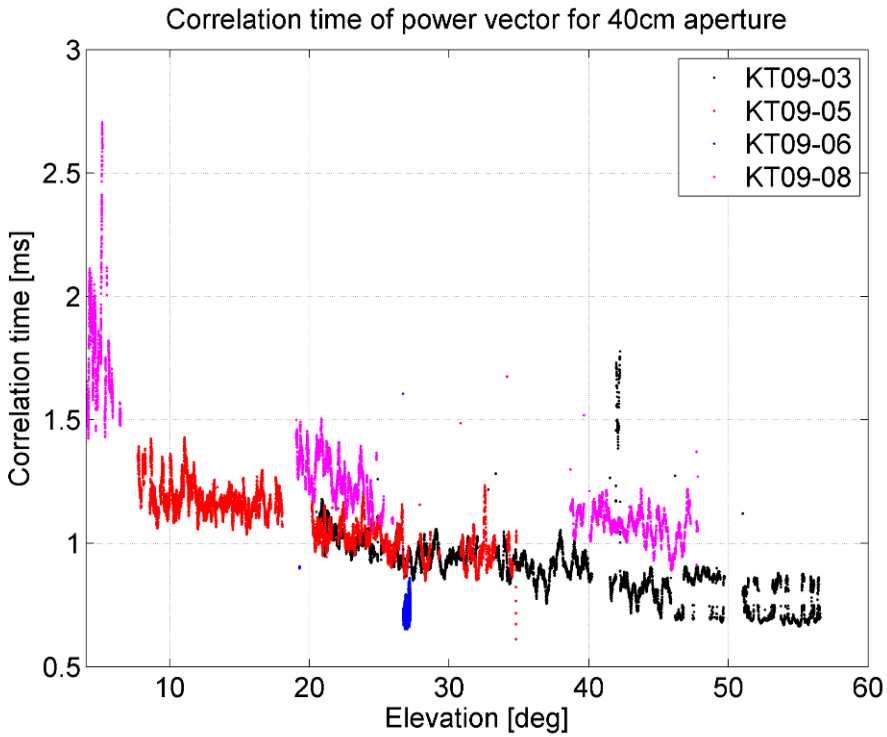
Analysis: Power measurements

- Correlation time for Trials #03, 05, 06, 08
- 50% correlation time of power vector

5cm aperture

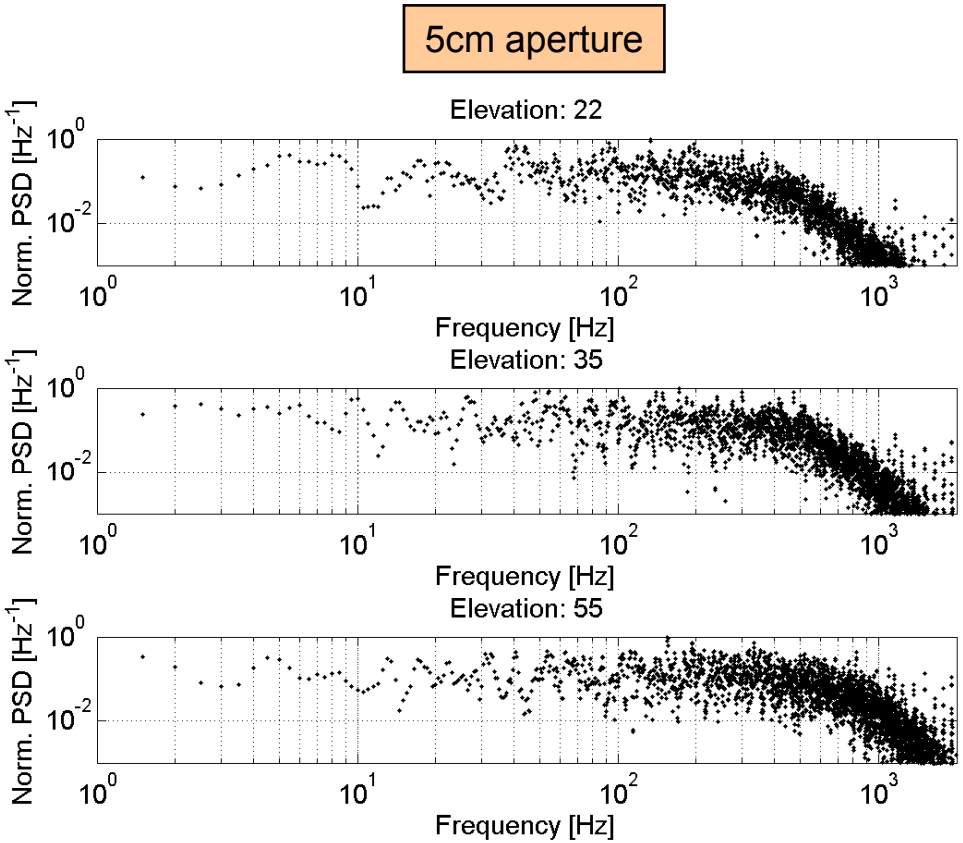


40cm aperture



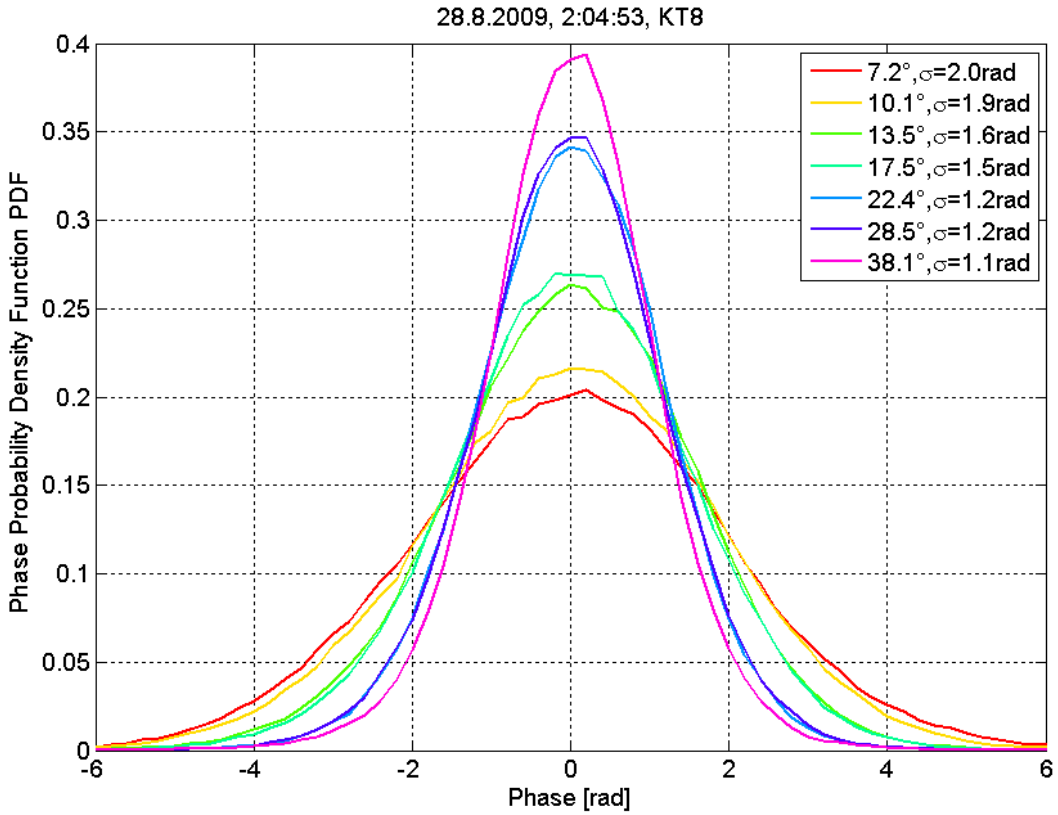
Analysis: Power measurements

- Normalized power spectral density for three elevations during Trial #03

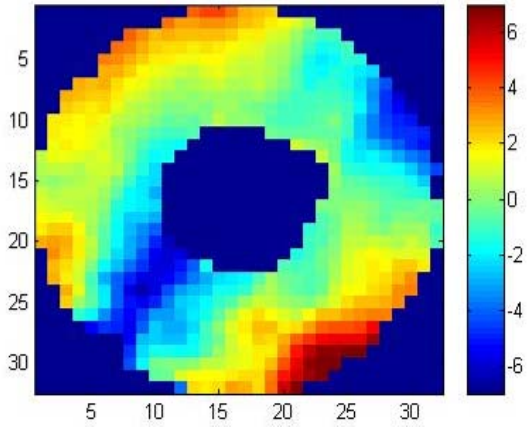


Analysis: Shack-Hartmann wave-front sensor

- Wave-front measurements during Trial #08 for chosen elevations → estimated probability density function of phase

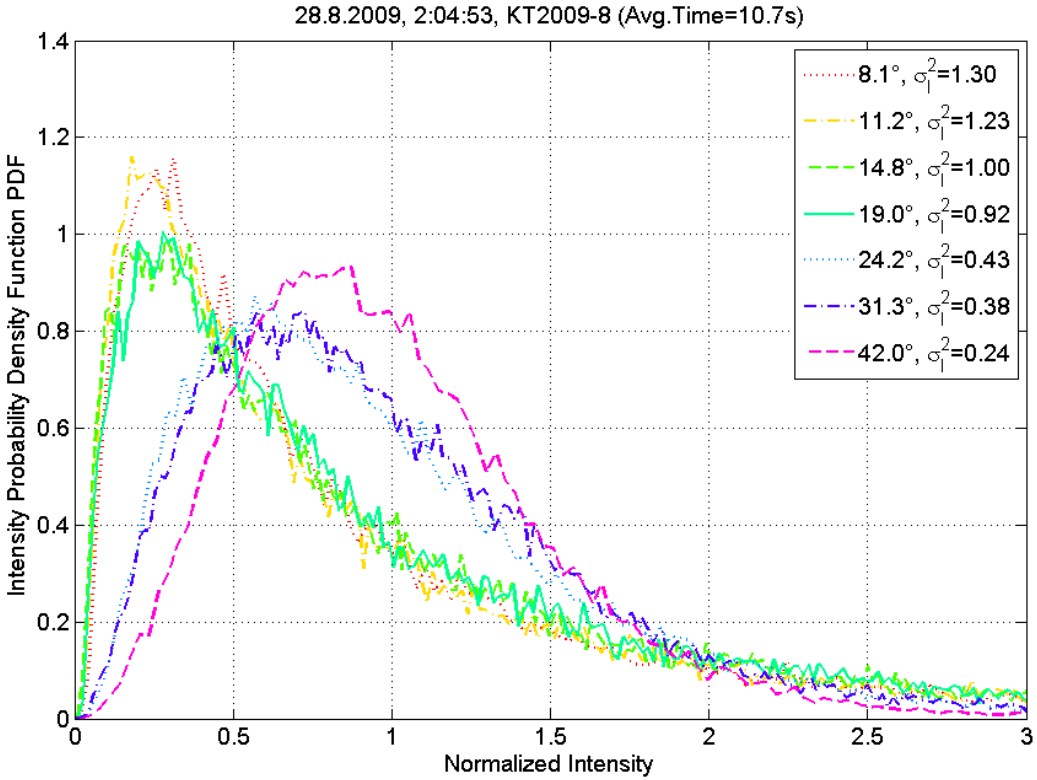


Example wave-front



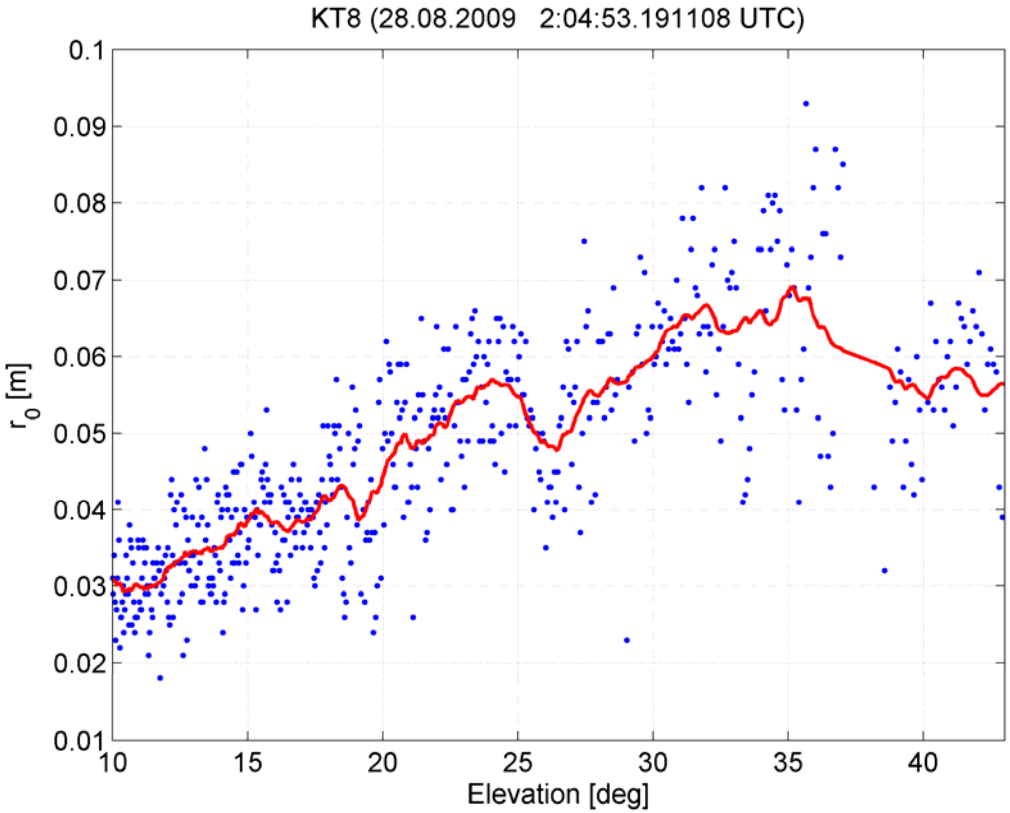
Analysis: Shack-Hartmann wave-front sensor

- PDF of Intensity derived from Shack-Hartmann images during Trial #08



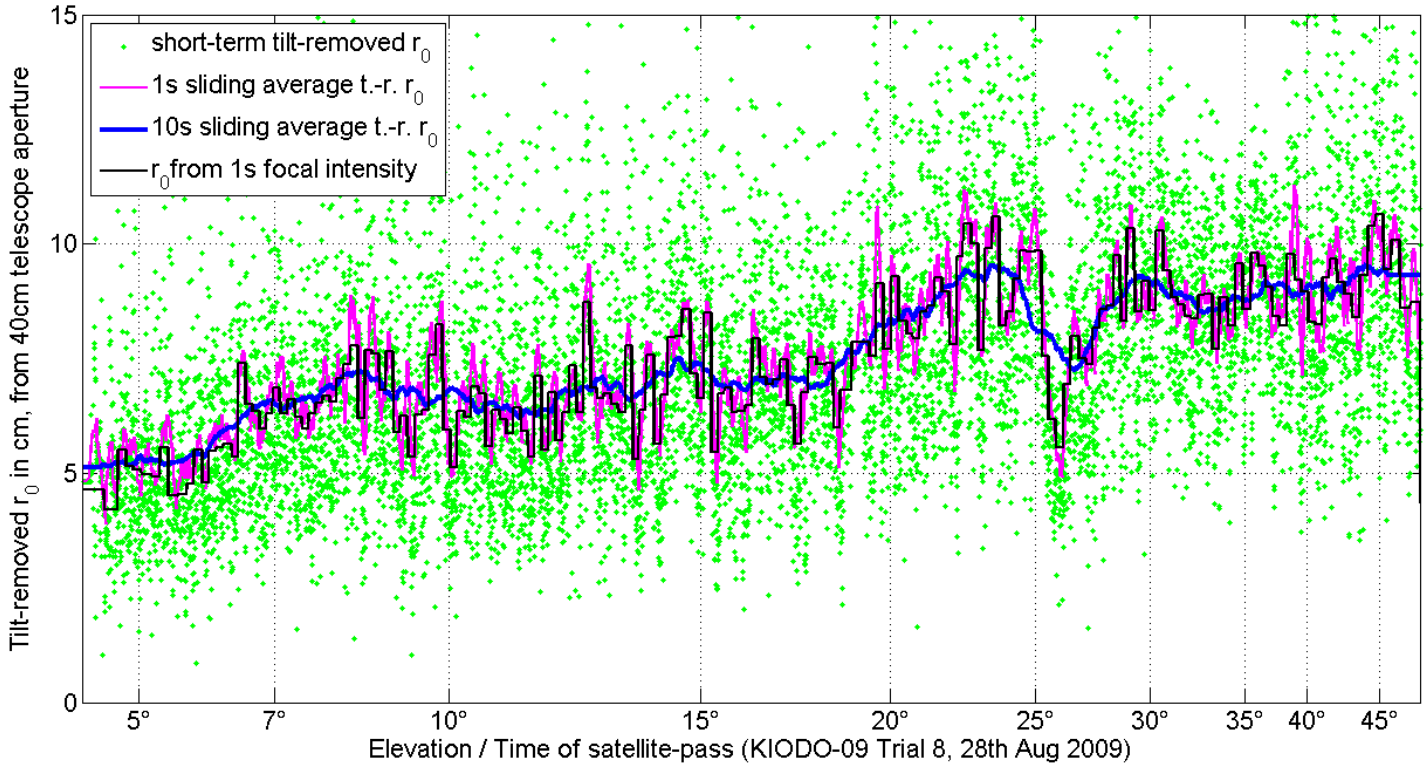
Analysis: Shack-Hartmann wave-front sensor

- Calculation of Fried parameter r_0 for Trial #08
- DIMM method applied to Shack-Hartmann images

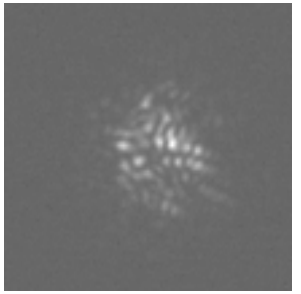


Analysis: Focus camera

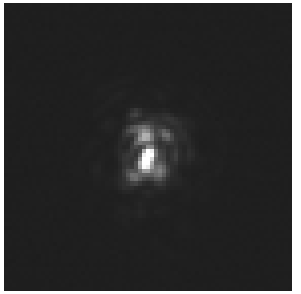
- Intensity measurements in focal plane during Trial #08
- Estimation of tilt removed r_0



Focus spot @ 5°

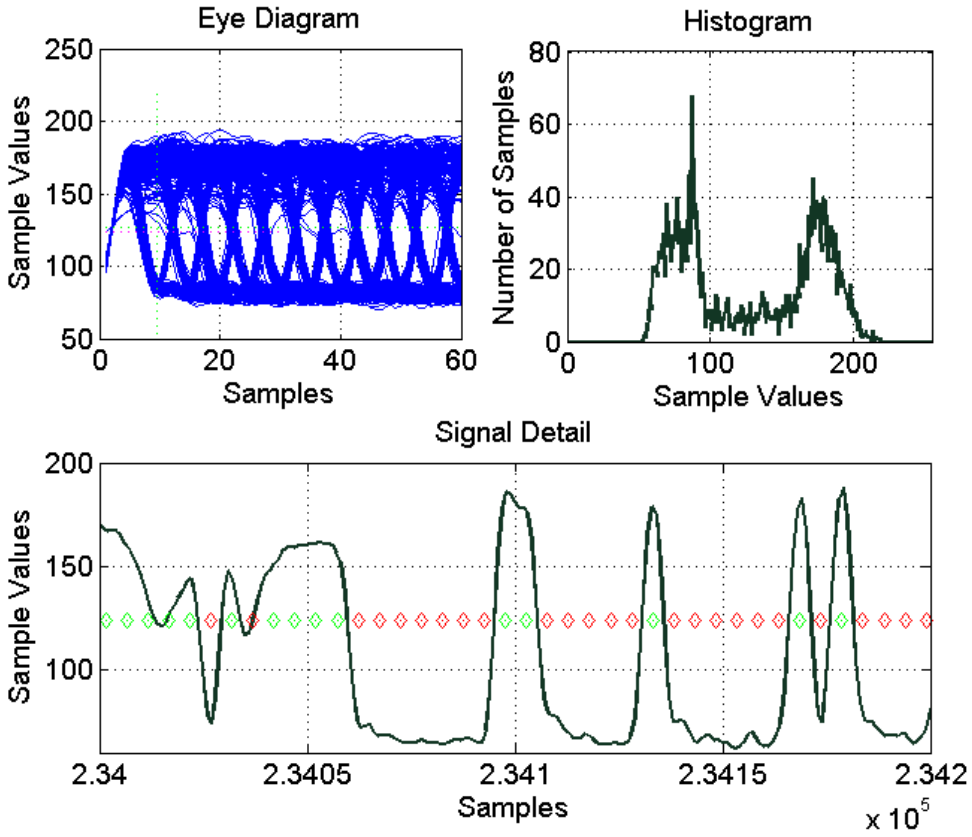


Focus spot @ 44°



Analysis: Data logger

- Received signal sampled at 250MS/s and 8 bit resolution
- 1ms example sequence from Trial #08



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Summary and outlook

- Five successful trials in 2009, four with usable data
- Data recorded with 40cm and 5cm aperture
- Measurements of power, wave-front, focus spot, pupil image, differential motion of focus spots
- Calculation of power scintillation index, correlation time, power PDF, power spectrum, wave-front, phase PDF, Fried parameter

- More extensive analysis of measurements from KIODO 2009
- Cross-check of measurement results with different measurement devices → r_0, σ_I^2, σ_P^2, etc.
- Combined analysis of trials 2006 and 2009 (10 successful trials) → towards channel model

That’s it…